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Travel Decisions & Their Implications for Urban Transportation: From Campus Transportation to Statewide Modeling

Gulsah Akar
Ohio State University - Main Campus

TRANSPORTATION CHOICES & THEIR IMPLICATIONS

From Campus Transportation to Statewide Modeling

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Seminar
Portland State University
May 1st, 2015

Bio

- The Ohio State University (OSU)
  - 2009-2010 Visiting Assistant Professor
  - 2010- present, Assistant Professor,
  - 2013- present, Master's Program Chair
- University of Maryland (UMD) Civil Engineering
  - PhD 2009, with a focus in Transportation
- METU Civil Engineering
  - BS 2002, MSc 2004

Today's Talk

- Research focus
- Detailed discussion on
  - Campus transportation related research
  - Integrated land-use transportation models
- Ongoing work

Research Overview

- Travel demand forecasting
- Travel behavior
- Links between land-use & transportation

- Special focus:
  - Modeling travel behavior, travel choices & individuals' perceptions.
  - Forecasting future transportation patterns under changing socio-economic, land-use & built environment scenarios.
  - Use of the latest methodological & conceptual advances.

Various Applications & Publications

- VMT (vehicle miles traveled) estimations with a focus on household vehicle fleet characteristics
- Traffic accident analysis
- Demand assessment for alternative modes for airport ground access
- Design & use of visual preference surveys to identify preferable street characteristics
- Siting future work facilities and their impacts on workers' transportation patterns
- Campus transportation
- Integrated land-use transportation models

Various Applications & Publications

- VMT (vehicle miles traveled) estimations with a focus on household vehicle fleet characteristics
- Traffic accident analysis
- Demand assessment for alternative modes for airport ground access
- Design & use of visual preference surveys to identify preferable street characteristics
- Siting future work facilities and their impacts on workers' transportation patterns
- **Campus transportation**
  - 5 published journal articles, 1 under review and 8 conference presentations.
- **Integrated land-use transportation models**
  - 2 funded research grants through ODOT, 1 journal article, 2 under review

CAMPUS TRANSPORTATION

Campuses

General Trends Extend to Campuses

- Auto travel (particularly single occupancy vehicle travel) is high and dominates the road design, financial policies and mode choice.
- Several experience congestion particularly during peak hours on campus roads and off-campus roads close to campus.
- Growing enrollments, growing parking demand.
- Although there is increasing awareness, still limited sources for alternative travel modes.

  - Congestion
  - Reduced air quality
  - Costly parking
  - Reduced quality of life
  - Reduced physical activity

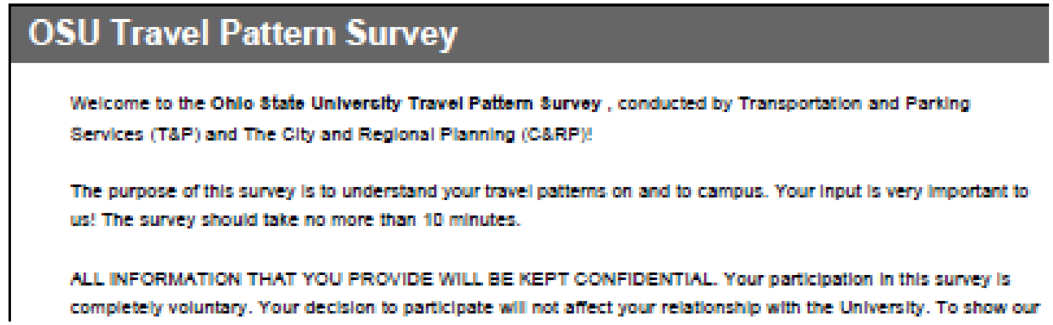
Why Focus on Campuses?

- There is an increasing interest among colleges and universities to
  - reduce local congestion,
  - reduce contributions to greenhouse gases,
  - provide leadership in sustainable development.

- Campus setting differs from the other urban areas
  - unique population with younger and more active individuals,
  - continuous movement of people throughout the day
  - irregular schedules.

- Reshaping society’s transportation patterns.
  - The behavior adopted in college years can disseminate to the whole nation.

Campus Travel Surveys



OSU Travel Pattern Survey

Welcome to the **Ohio State University Travel Pattern Survey** , conducted by Transportation and Parking Services (T&P) and The City and Regional Planning (C&RP)!

The purpose of this survey is to understand your travel patterns on and to campus. Your input is very important to us! The survey should take no more than 10 minutes.

ALL INFORMATION THAT YOU PROVIDE WILL BE KEPT CONFIDENTIAL. Your participation in this survey is completely voluntary. Your decision to participate will not affect your relationship with the University. To show our

University of Maryland, 2008
The Ohio State University, 2010-14

G. Akar, K. J. Clifton (2009) “The influence of individual perceptions and bicycle infrastructure on the decision to bike” *Transportation Research Record (TRR)*, Vol. 2140, pp. 165-172, (citations: 72)

G. Akar, C. Flynn and M. Namgung (2012) “Travel Choices and Links to Transportation Demand Management”, *Transportation Research Record (TRR),* Vol. 2319, pp. 77-85, (citations: 6)

G. Akar, N. Fischer and M. Namgung (2013) “Bicycling Choice and Gender, Case study: The Ohio State University”, *International Journal of Sustainable Transportation*, Vol. 7, Issue 5, pp. 347-365, (citations: 17)

M. Namgung and G. Akar (2014) “The Role of Gender and Attitudes on Public Transportation Use” *Transportation Research Record (TRR)* Vol. 2415, pp. 136-144

C. Wang, G. Akar and JM Guldmann (2015) “Do Your Neighbors Affect Your Bicycling Choice: A Spatial Probit Model for Bicycling to The Ohio State University” *Transport Geography,* 42, 122-130

M. Namgung and G. Akar (2015) "Influences of Neighborhood Characteristics and Personal Attitudes on University Commuters’ Public Transit Use, accepted, *Transportation Research Record (TRR)*

Background

- Early research identifies travel time and cost as the most important determinants of mode choice.

- Long line of research on land-use and travel behavior (sometimes ambiguous):
  - Employment density, population density, and land-use mix are positively related to transit, biking and walking, and negatively related to auto use.

- Effects of individuals' attitudes toward travel time, cost, comfort, convenience, reliability, and safety have been the focus of several studies within the past decade.

- Causality: whether the built environment determines travel behavior or whether the reverse is true.
  - Residential self-selection. If individuals' attitudes influence how they choose their residential locations, the effects of altering the built environment - density and land-use - may be overstated and overestimated.

Research Questions

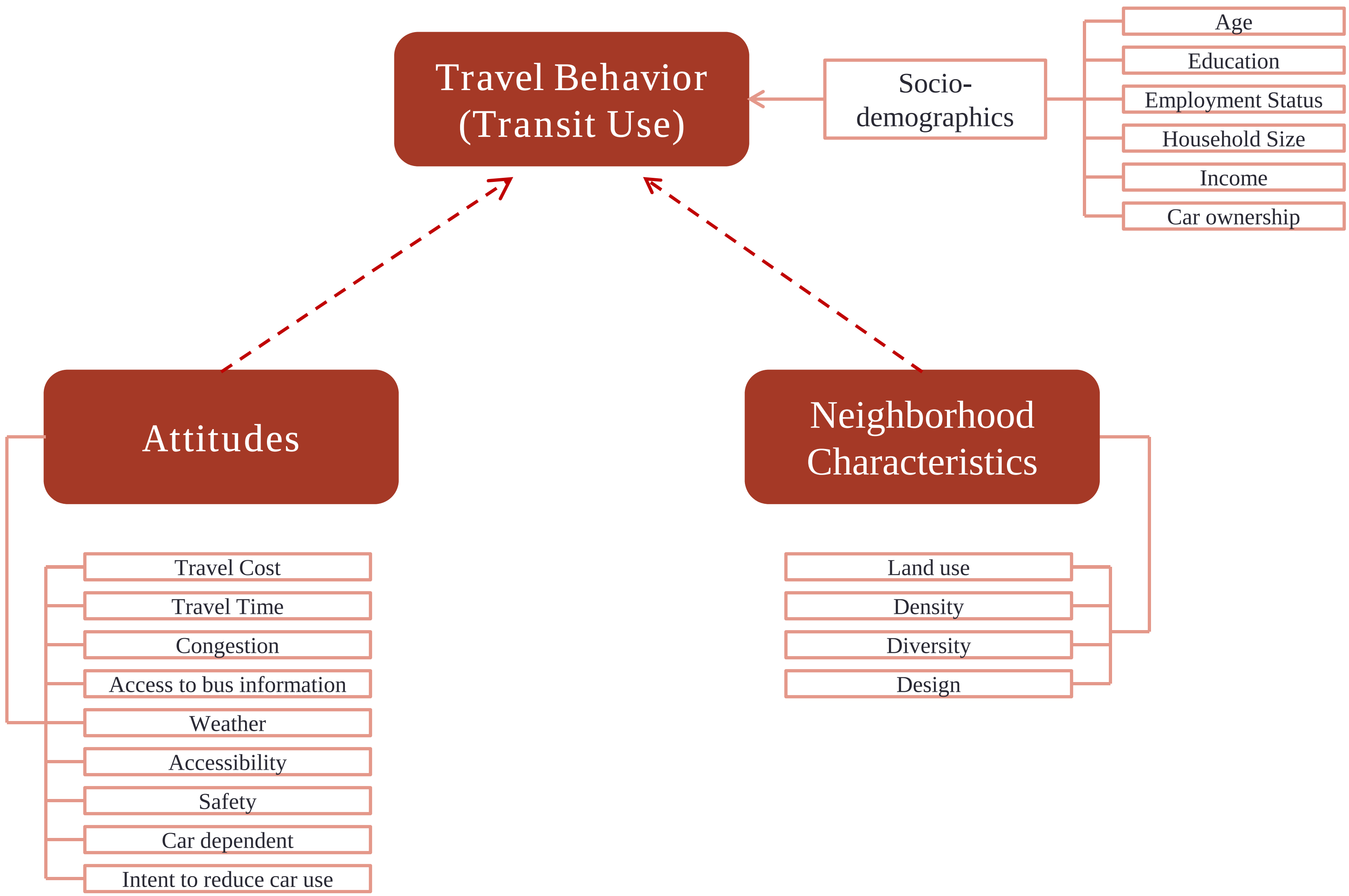
1) Do attitudes toward public transit affect public transit use? If so, how do attitudes affect people's transit use?

2) Does the built environment affect public transit use? If so, how does the built environment influence people's transit use?

3) Do the attitudinal factors, neighborhood types or a combination of both explain the resulting transit use better?

4) Is there evidence of residential-self selection effects?

Conceptual Framework



The Ohio State University (OSU)

OSU's main campus in Columbus, Ohio is one of the area's largest employers generating a large amount of traffic in the area. ~80,000 people attend/work at OSU.

- Campus Area Bus Service (CABS)
- The Central Ohio Transit Authority's (COTA)

Commute mode: Transit

- OSU (2012): 16%
- Portland State University (2011): 39%
- University of North Texas (2012): 25%
- Indiana University (2012): 29%

Data Collection

- Data collection started on *May 3, 2012* and ended on *May 19, 2012.*

- Web-based survey available via two sources:
  - Collector 1
    - Emails sent by the research team to a randomly selected sample
      - Sent to 21,500 email addresses - ~25% of the campus pop.
    - **2,643** responses
  - Collector 2
    - Links available to the public: university e-newsletters
    - **642** responses

- A total of 3,285 respondents began the survey and 2,638 respondents completed the survey.

Survey questions

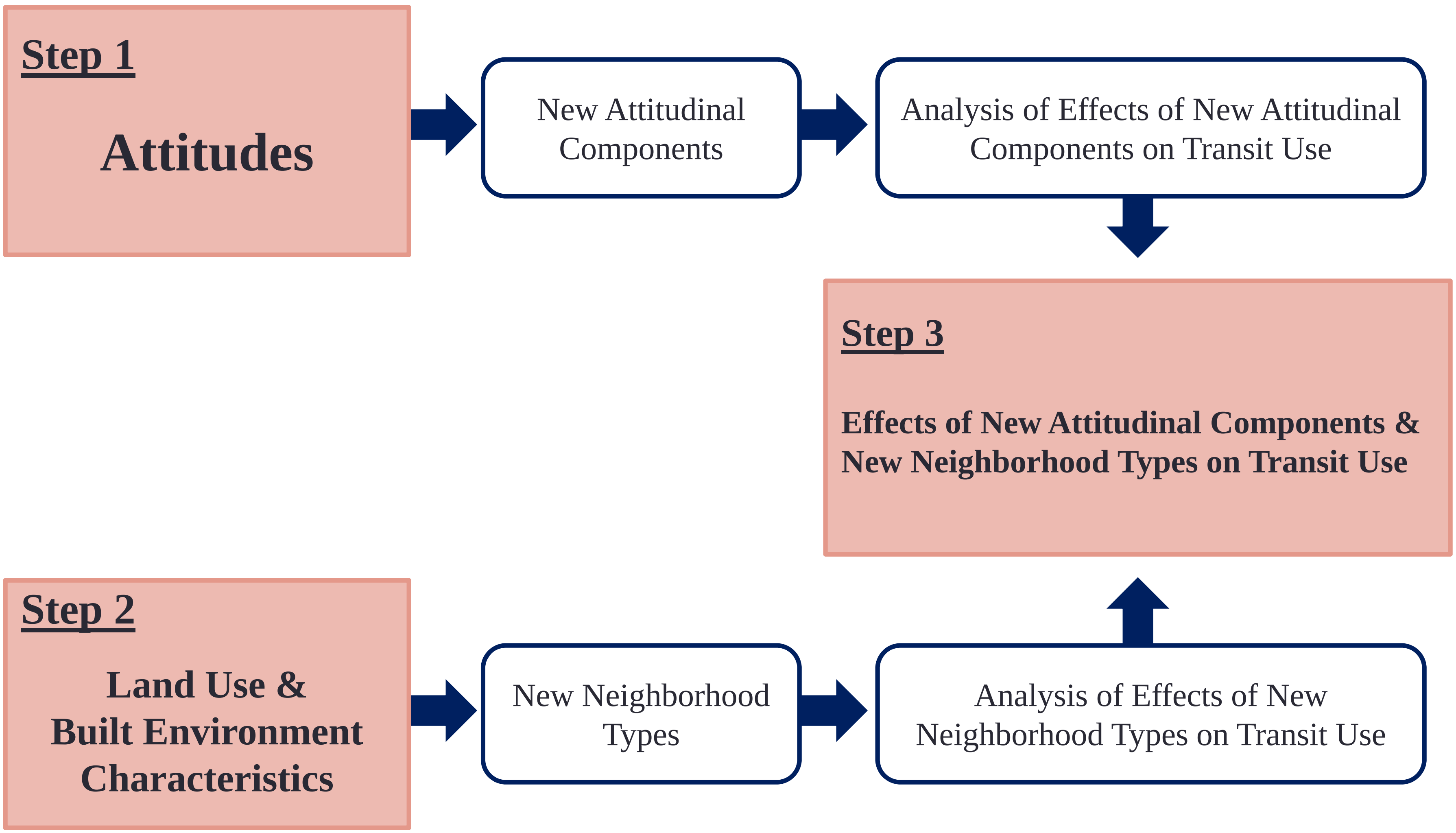
- ❑ Commute mode choices
- ❑ Residential locations
- ❑ Socio-demographic characteristics :
  - Status (undergraduate student, graduate student, faculty, staff)
  - Gender
  - Ethnicity
  - Car ownership
- ❑ Attitudes towards driving and taking public transit including reliability, safety, flexibility, convenience, accessibility and comfort

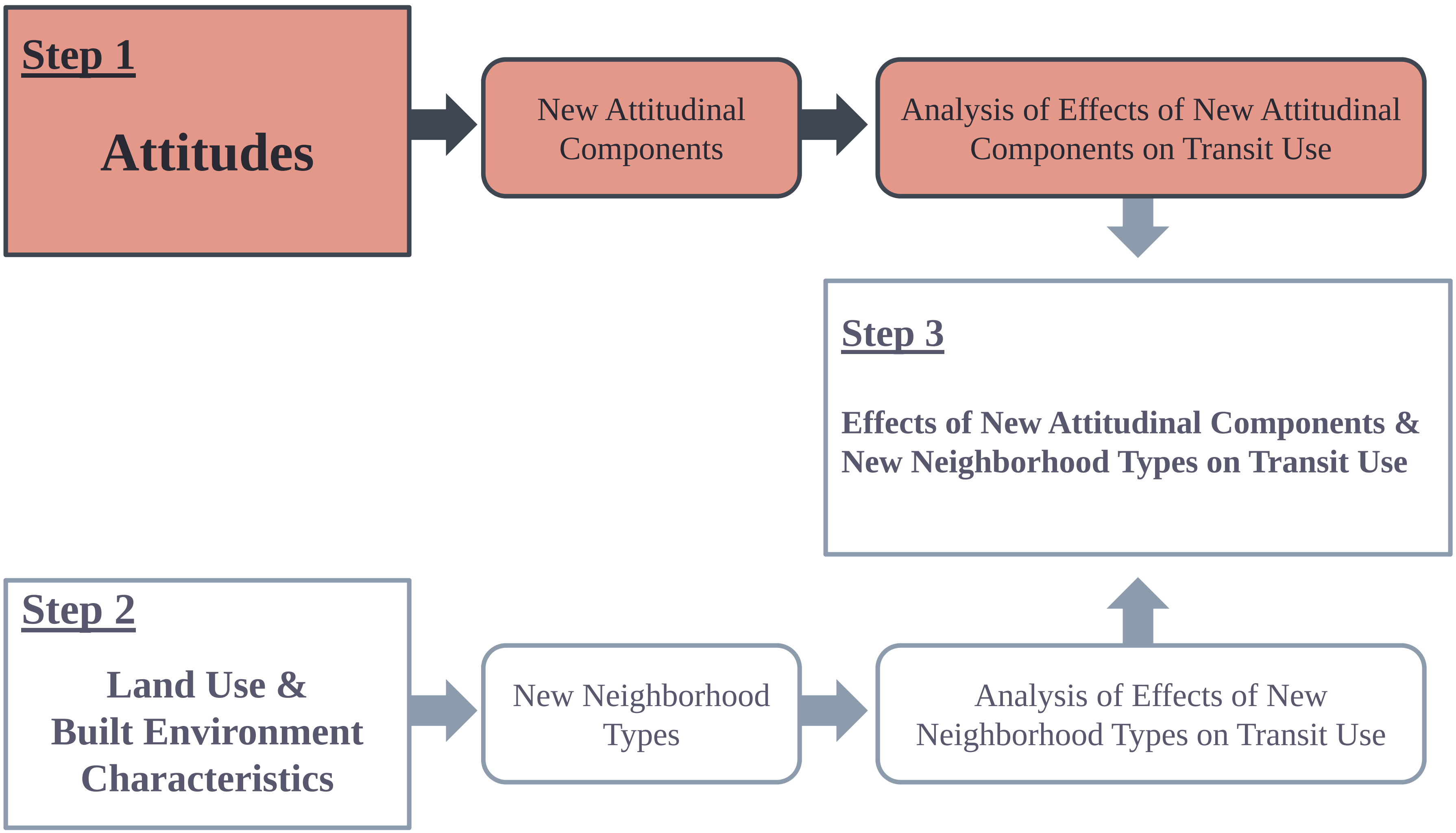
Transit choice of off-campus residents

Transit user: an individual uses public transit at least once a week for their commute.

	Transit User (%)	Non-Transit User (%)	N
Status			
Faculty	15.6%	**84.4%**	186
Staff	10.6%	**89.4%**	781
Graduate Student	40.2%	59.8%	301
Undergraduate Student	**58.7%**	41.3%	688
Location			
Less than a mile	**44.9%**	55.1%	425
1 to 5 miles	**44.4%**	55.6%	685
6 to 10 miles	23.5%	**76.5%**	425
11 to 15 miles	19.4%	**80.6%**	392
More than 16 miles	19.3%	**80.7%**	388
Bus stop			
1 to 5 minutes	**45.0%**	55.0%	797
6 to 10 minutes	38.4%	61.6%	315
11 to 15 minutes	27.3%	72.7%	154
16 to 20 minutes	19.3%	80.7%	57
Over 20 minutes	20.6%	79.4%	248
Gender			
Female	32.0%	68.0%	1,159
Male	33.1%	66.9%	794
Total	**32.2%**	**67.8%**	2,320

Research Design

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New Attitudinal Components
Analysis of Effects of New Attitudinal Components on Transit Use
Step 3
Effects of New Attitudinal Components & New Neighborhood Types on Transit Use
Step 2
Land Use & Built Environment Characteristics
New Neighborhood Types
Analysis of Effects of New Neighborhood Types on Transit Use

Attitudinal Statements

1. I often make other trips during my commute to campus.
2. I often change my daily travel plans.
3. Transferring buses does not bother me.
4. Saving travel time is more important than saving money.
5. Taking the bus lengthens my commute.
6. Even if gas prices and parking costs go up, I would use my auto as a commuting mode.
7. Taking the bus gives me the opportunity to save money.
8. If the buses come often enough, I would use the bus more often.
9. If the buses arrive on time, I would use the bus more often.
10. I enjoy driving alone.
11. The bus routes and scheduling information are accurate.
12. Transit service is available where I live.
13. I feel safe at bus stops/on the bus.
14. If the buses were not overcrowded, I would use public transit more often.
15. Buses are clean enough.
16. Where I choose to live is affected by transit service availability.
17. I know where to access bus schedules and route information.
18. It is not a hassle to search for transit related information.
19. I feel more comfortable in my auto than on the buses.
20. I read books or do other stuff on the bus.
21. I enjoy interacting with others on the bus.
22. Traffic congestion is more tolerable than bus delays.
23. Driving on the congested roadway is very stressful.
24. Traffic congestion is not so bad on/around campus.
25. Driving in traffic congestion is more stressful than waiting for the bus or bus transfers.
26. I prefer transit to avoid the stress from finding a parking spot.
27. During the period of heavy snow or rain, I prefer transit over driving.
28. I enjoy spending my time on the bus reading or listening to music.
29. Regardless of adverse environment impacts, I prefer driving.
30. I see transit as an environmentally friendly travel option.
31. I am actively trying to use my car less often.
32. I have no interest in reducing my car use.
33. My friends usually take public transit.
34. My family usually takes public transit.
35. My co-workers usually take public transit.
36. I don't have a car or I don't use one to come to campus.
37. My lifestyle is dependent on having a car.
38. I don't think about my travel options; I just get in my car and go.
39. I have no other option but to drive to campus.
40. Shorter commute time is important in mode choice.
41. More flexibility in when I depart from campus is important in mode choice.
42. The ability to make stops on the way to and from campus is important in mode choice.
43. Safety from crime is important in mode choice.
44. Safety in traffic is important in mode choice.
45. Extreme weather conditions is are an important consideration in mode choice.
46. Cost is important in mode choice.
47. Concern for the environment is important in mode choice.

23 attitudinal statements

1. I don't think about my travel options; I just get in my car and go
2. I have no interest in reducing my car use
3. I enjoy driving alone
4. Regardless of adverse environment impacts, I prefer driving
5. If the buses come often enough, I would use the bus more often
6. If the buses arrive on time, I would use the bus more often
7. If the buses were not overcrowded, I would use public transit more often
8. I often make other trips during my commute to campus
9. I often change my daily travel plans
10. Saving travel time is more important than saving money
11. Taking the bus lengthens my commute
12. My friends usually take public transit
13. My family usually takes public transit
14. My co-workers usually take public transit
15. I read books or do other stuff on the bus
16. I enjoy spending my time on the bus reading or listening to music
17. Transit service is available where I live
18. I know where to access bus schedules and route information
19. It is not a hassle to search for transit related information
20. Driving on the congested roadway is very stressful
21. Driving in traffic congestion is more stressful than waiting for the bus or bus transfers
22. Safety from crime is important in mode choice
23. Safety in traffic is important in mode choice

Principal Component Analysis (PCA)

Results of the PCA

Statements	Principal component
• I don't think about my travel options; I just get in my car and go • I have no interest in reducing my car use • I enjoy driving alone • Regardless of adverse environment impacts, I prefer driving	**PC 1: Preference of car use**
• If the buses come often enough, I would use the bus more often • If the buses arrive on time, I would use the bus more often • If the buses were not overcrowded, I would use public transit more often	**PC 2: Willingness to use transit**
• I often make other trips during my commute to campus • I often change my daily travel plans • Saving travel time is more important than saving money • Taking the bus lengthens my commute	**PC 3: Need for flexibility/ sensitivity to time**
• My friends usually take public transit • My family usually takes public transit • My co-workers usually take public transit	**PC 4: Transit use around a traveler**
• I read books or do other stuff on the bus • I enjoy spending my time on the bus reading or listening to music	**PC 5: Ability to rest or read**
• Transit service is available where I live • I know where to access bus schedules and route information • It is not a hassle to search for transit related information	**PC 6: Perceived availability of transit service/ familiarity with bus information access**
• Driving on the congested roadway is very stressful • Driving in traffic congestion is more stressful than waiting for the bus or bus transfers	**PC 7: Sensitivity to congestion**
• Safety from crime is important in mode choice • Safety in traffic is important in mode choice	**PC 8: Sensitivity to safety**

Model Specification – Binary Logit

- The probability of being a transit user for traveler *n* is given by the following:

$$\mathrm{P}_n(\mathrm{i}\,) = \Pr(U_n(i)\ \geq\ U_n(\,j))$$

Where, *U* is the utility of the given alternative, and *i* and *j* are alternatives in the choice set for traveler *n.*

- $U_n(i)$ represents the utility of being a transit user for traveler *n*. There are two alternatives, *i* and *j* in this study: *i* is being a transit user, *j* is otherwise.

$$U_n(\mathrm{i}) =\ \beta_i x_{ni} +\ \varepsilon_{ni}$$

where, $U_n(i) and\ U_n(j)$ are utility functions. x_{ni} is observed variables that relates to the individual, β_i is a vector of coefficients, and ε_{ni} is the random error term.

- Binary logit function can be written as follows:

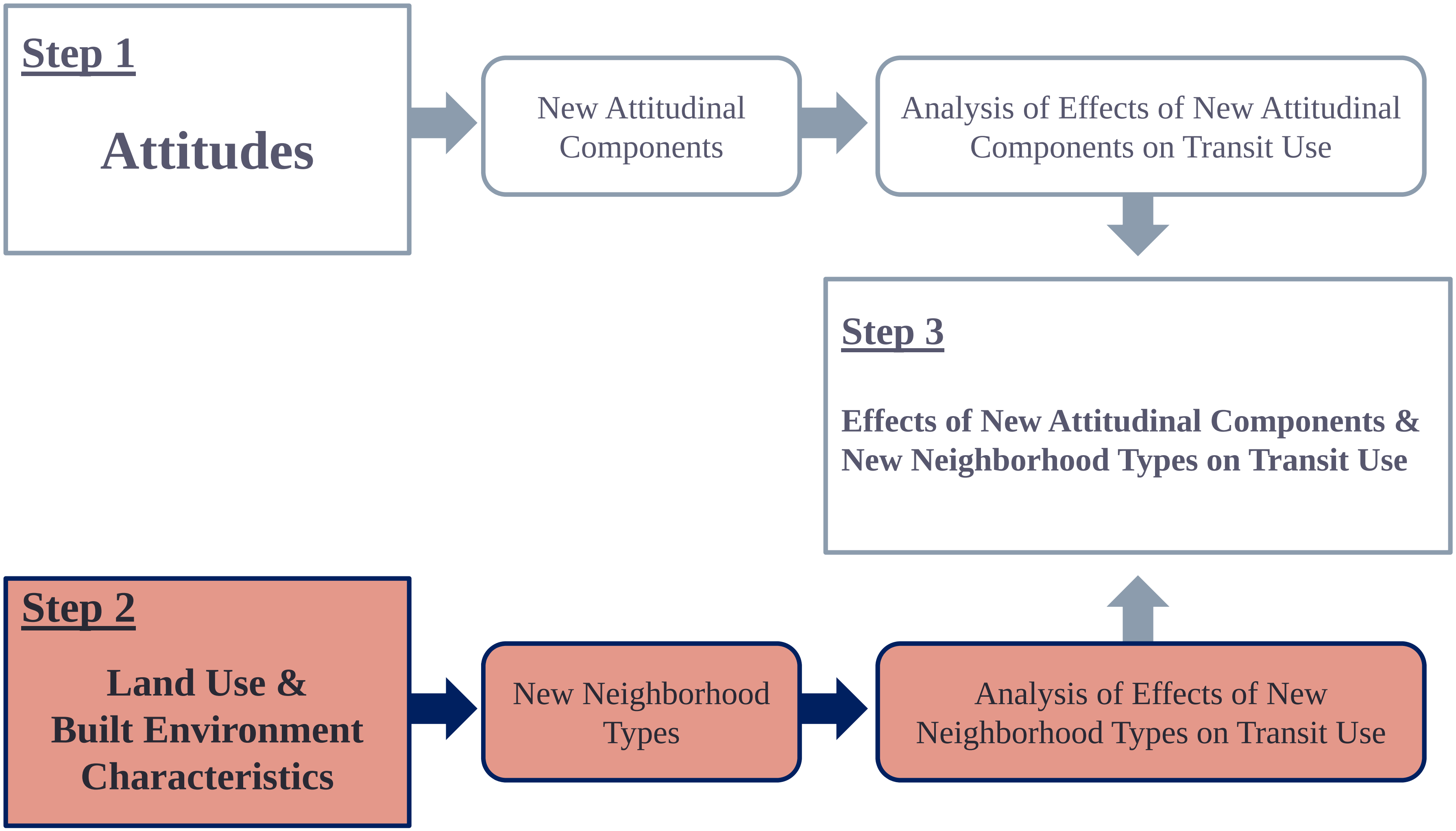
$$\mathrm{P}_n(\mathrm{i}\,) = \frac{1}{1 + e^{\beta(x_{nj}-x_{ni})}}$$

Model results

Base case: being a non-transit user

	Model 1		
Variable	Coef.	z stat.	Marginal Effect
Constant	0.583	1.31	
Socioeconomic variables (undergraduate student is the base case)			
Faculty	**-1.833**	**-3.58**	**-42.1**
Staff	**-2.238**	**-7.18**	**-48.4**
Graduate student	**-1.261**	**-3.99**	**-30.5**
Female	0.329	1.44	7.1
Ethnicity (non_white)	0.361	1.19	7.7
Service			
Bus stops (within 0.25 miles)	-0.245	-0.65	-5.8
Locations (1-5 miles is the base case)			
Less than a mile	**-0.903**	**-2.89**	**-33.9**
6 miles to 10 miles	0.114	0.35	2.6
11 miles to 15 miles	0.393	0.96	8.3
More than 15 miles	-0.419	-0.76	-10.0
Principal Components			
PC 1: Preference of car use	**-0.199**	**-2.20**	**-5.7**
PC 2: Willingness of transit use	**0.275**	**3.10**	**8.2**
PC 3: Need for flexibility/ Sensitivity to time	**-0.284**	**-3.15**	**-9.5**
PC 4: Transit use around a traveler	**0.165**	**1.98**	**5.0**
PC 5: Ability to rest or read	**0.293**	**3.29**	**8.3**
PC 6: Perceived availability of transit service/ familiarity with bus information access	0.126	1.32	3.5
PC 7: Sensitivity to congestion	0.137	1.41	3.8
PC 8: Sensitivity to safety	**-0.215**	**-2.19**	**-7.7**
Number of observations (N)	533		
Initial Log likelihood	-359.4324		
Final Log likelihood	-265.95233		

Bolded coefficients are significant at the 95% level and italicized coefficients are significant at the 90% level. For marginal effects, the probability of being a transit user is calculated at means for continuous variables and at zero for dummy variables. The probability of being a transit user at means is 64.5%.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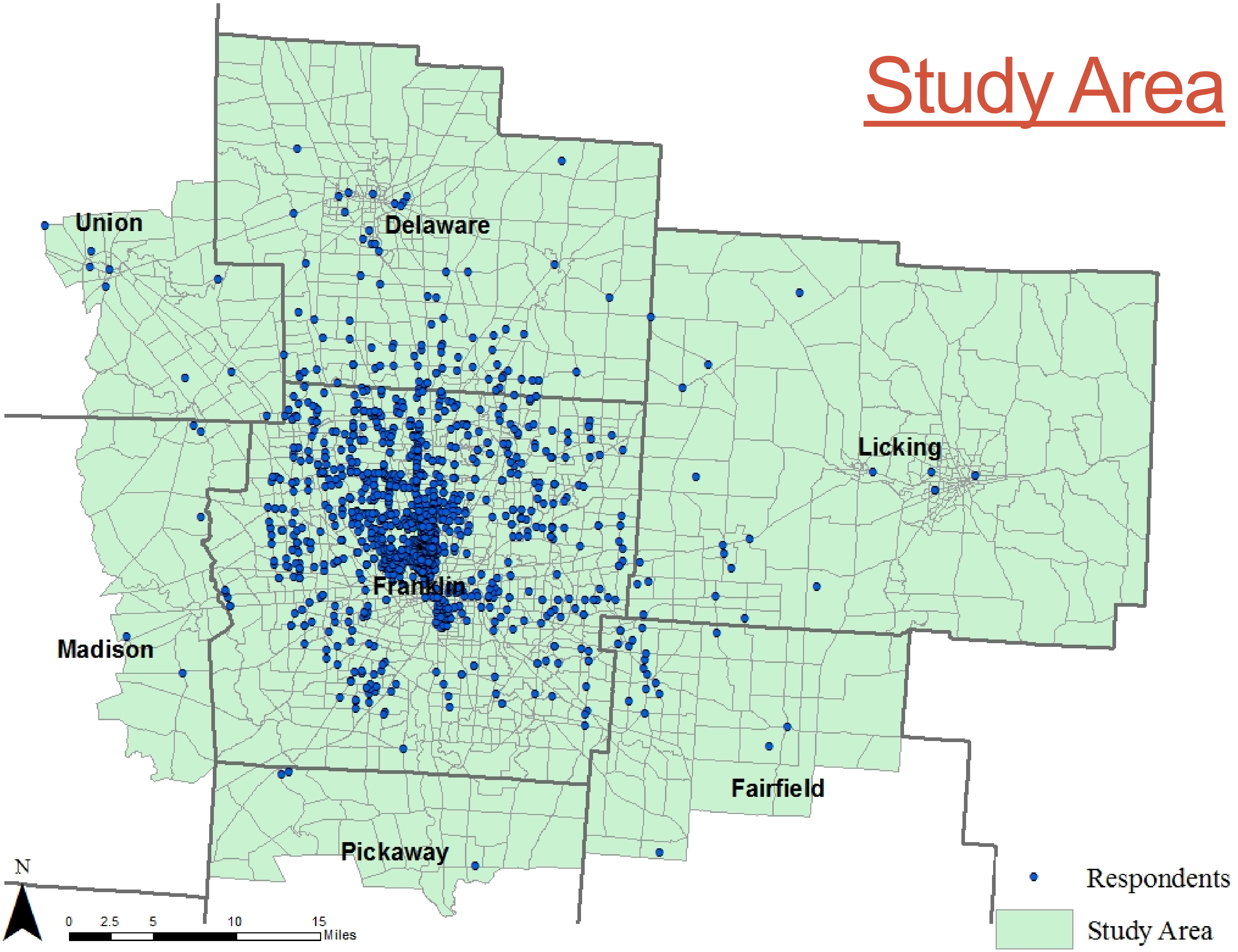
Study Area


Union
Delaware
Licking
Madison
Franklin
Fairfield
Pickaway
N
0 2.5 5 10 15
Miles
Respondents
Study Area

Built Environment Variables

- Population Density
- Employment Density
- Housing Density
- Median Age of Structures
- Percentage of Single Family Housing
- Intersection Density

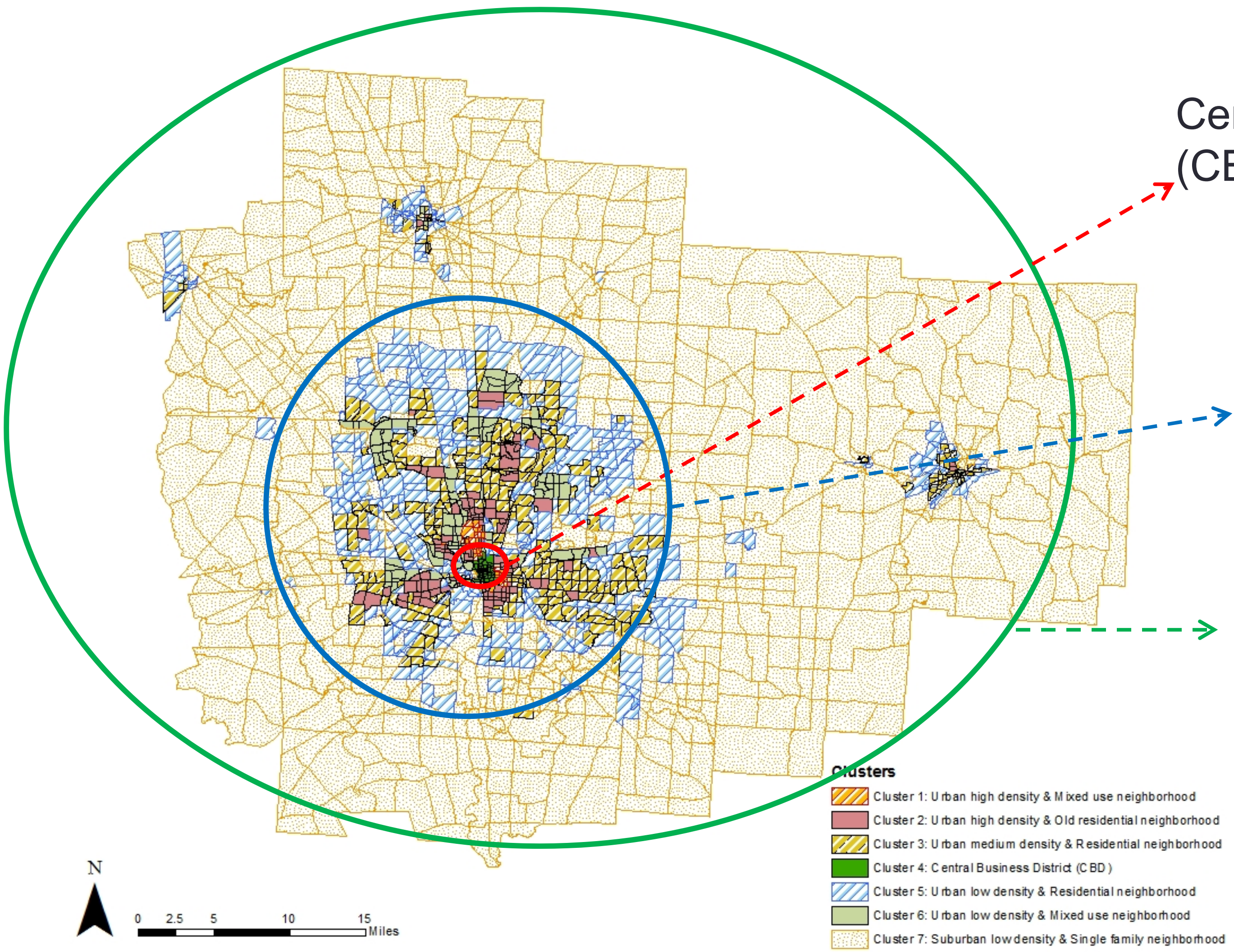
➡ *K*-means Cluster Analysis

Results of the Cluster Analysis

Variables		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Total
Population Density (persons/sq. mi)	Mean	11488.5	7785.4	4529.7	3213.8	2052.6	1857.7	284.1	2301.2
	SD	7014.6	1692.8	890.5	3761.8	710.5	1386.7	322.9	2892.1
Employment Density (persons/sq. mi)	Mean	9898.3	2450.6	1403.0	31323.7	983.6	5114.0	244.5	2341.6
	SD	3706.3	1767.9	879.0	2925.8	731.0	2009.6	405.9	5934.6
Housing Density (house/sq. mi)	Mean	5207.9	3481.1	1738.3	1651.2	900.3	1301.0	192.6	1042.7
	SD	2103.2	1222.0	787.4	893.1	560.1	930.0	232.9	1269.4
Intersection Density	Mean	240.4	165.4	104.2	303.1	57.7	90.1	12.8	67.6
	SD	168.9	84.4	64.2	145.6	39.1	86.1	19.7	90.4
Median Age of Structures	Mean	57.3	56.2	44.5	41.8	32.8	41.3	33.1	37.7
	SD	5.6	11.5	14.4	12.5	13.5	15.5	9.8	14.1
Percent Single Detached House	Mean	27.1	47.1	60.3	3.5	63.3	41.6	79.1	64.3
	SD	12.7	21.3	20.3	4.5	21.2	20.4	19.2	26.3
Number of TAZs		37	116	303	64	401	110	774	1805
Number of Respondents		362	371	405	12	263	130	97	1640

- **Cluster 1: Urban high-density & Mixed-use neighborhoods**
- **Cluster 2: Urban high-density & residential neighborhoods**
- **Cluster 3: Urban medium-density & Residential neighborhoods**
- **Cluster 4: Central Business District (CBD)**
- **Cluster 5: Urban low-density & Residential neighborhoods**
- **Cluster 6: Urban low-density & Mixed-use neighborhoods**
- **Cluster 7: Suburban low-density & Single-family neighborhoods**

Results of the Cluster Analysis



Central Business District (CBD): Cluster 4

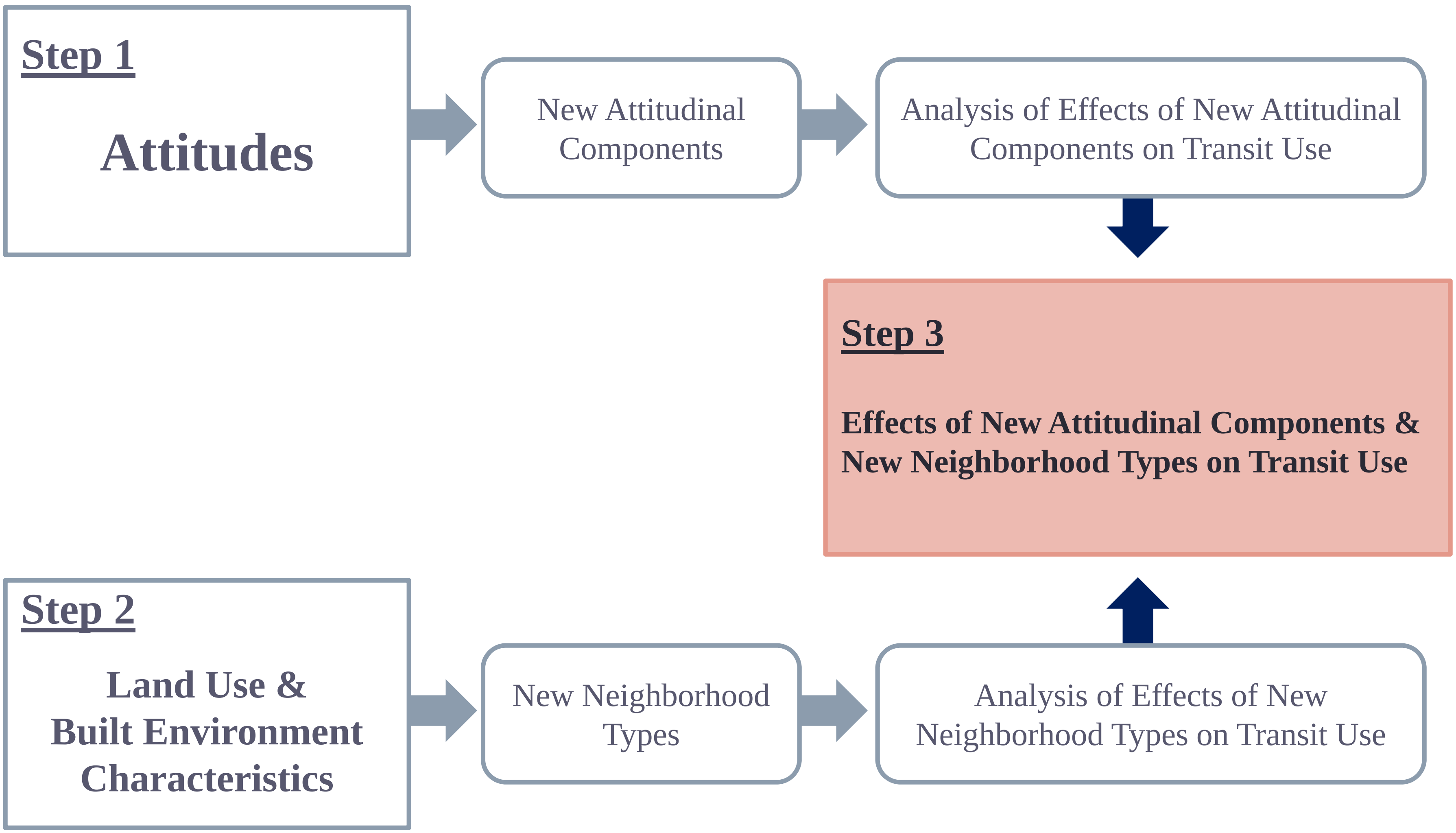
Urban Area: Cluster 1, 2, 3, 5, 6

Suburban Area: Cluster 7

Model results

Base case: being a non-transit user

	Model 2		
Variable	Coef.	z stat.	Marginal Effects
Constant	**1.188**	**4.20**	
Socioeconomic vars (undergraduate student -base case)			
Faculty	**-1.780**	**-4.03**	**-41.0**
Staff	**-2.241**	**-7.99**	**-50.8**
Graduate student	**-1.001**	**-3.63**	**-22.0**
Female	0.163	0.81	2.8
Ethnicity (non-white)	*0.447*	*1.66*	*7.1*
Locations (1-5 miles is the base case)			
Less than a mile	*-0.625*	*1.88*	*-12.9*
6 miles to 10 miles	-0.205	-0.64	-3.9
11 miles to 15 miles	-0.105	-0.27	-1.9
More than 15 miles	-0.461	-0.90	-9.2
Clusters (Cluster 2: Urban high-density & Old residential neighborhoods is the base case)			
Cluster 1: Urban high-density & Mixed-use neighborhoods	**-0.741**	**-2.27**	**-15.7**
Cluster 3: Urban medium-density & Residential neighborhoods	**-0.682**	**-2.21**	**-14.3**
Cluster 5: Urban low-density & Residential neighborhoods	**-0.877**	**-2.09**	**-18.9**
Cluster 6: Urban low-density & Mixed-use neighborhoods	**-1.113**	**-2.56**	**-24.8**
Cluster 7: Suburban low-density & Single-family neighborhoods	**-1.991**	**-1.97**	**-45.7**
Number of observations (N)	533		
Initial Log likelihood	-359.4324		
Final Log likelihood	-306.49029		
Bolded coefficients are significant at the 95% level and coefficients in italics are significant at the 90% level. For marginal effects, the probability of being a transit user is calculated at zero for dummy variables. The probability of being a transit user at means is 76.6%.			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Model Specification

Model 1: *attitudinal factors* and socio-demographics

Model 2: *the built environment* & socio-demographics

Model 3: *attitudinal factors, the built environment* & socio-demographic variables

	Model 1		Model 2		Model 3	
Variable	Coef.	z stat.	Coef.	z stat.	Coef.	z stat.
Constant	0.357	1.29	**1.188**	**4.20**	**0.851**	**2.56**
Socioeconomic variables						
(undergraduate student is the base case)						
Faculty	**-1.841**	**-3.59**	**-1.780**	**-4.03**	**-1.932**	**-3.65**
Staff	**-2.254**	**-7.24**	**-2.241**	**-7.99**	**-2.375**	**-7.33**
Graduate student	**-1.270**	**-4.03**	**-1.001**	**-3.63**	**-1.378**	**-4.24**
Female	0.331	1.45	0.163	0.81	0.293	1.27
Ethnicity (non-white)	0.361	1.19	0.447	1.66	0.371	1.19
Locations						
(1-5 miles is the base case)						
Less than a mile	**-0.914**	**-2.93**	*-0.625*	*1.88*	*-0.632*	*-1.76*
6 miles to 10 miles	0.158	0.49	-0.205	-0.64	0.227	0.62
11 miles to 15 miles	0.491	1.30	-0.105	-0.27	0.683	1.53
More than 15 miles	-0.274	0.55	-0.461	-0.90	-0.003	0.00
PC 1: Preference of car use	**-0.197**	**-2.17**			**-0.204**	**-2.22**
PC 2: Willingness of transit use	**0.265**	**3.04**			**0.252**	**2.85**
PC 3: Need for flexibility/ Sensitivity to time	**-0.280**	**-3.11**			**-0.252**	**-2.78**
PC 4: Transit use around a traveler	**0.167**	**2.01**			**0.172**	**2.04**
PC 5: Ability to rest or read	**0.293**	**3.29**			**0.297**	**3.32**
PC 6: Perceived availability of transit service/ familiarity with bus information access	0.121	1.27			0.100	1.04
PC 7: Sensitivity to congestion	0.140	1.44			0.159	1.61
PC 8: Sensitivity to safety	**-0.213**	**-2.18**			**-0.194**	**-1.97**
Neighborhoods						
(High-density, old is the base case)						
High-density, mixed use			**-0.741**	**-2.27**	**-0.814**	**2.28**
Medium density, residential			**-0.682**	**-2.21**	-0.564	-1.59
Low density, residential			**-0.877**	**-2.09**	-0.731	-1.49
Low density, mixed use			**-1.113**	**-2.56**	**-0.946**	**-1.97**
Suburban low density, single family			-1.991	-1.37	-0.980	-1.13
Number of observations (N)	533		533		533	
Initial Log likelihood	-359.4324		-359.4324		-359.4324	
Final Log likelihood	-266.1624		-306.49029		-261.85128	

Bolded coefficients are significant at the 95% level and coefficients in italics are significant at the 90% level

Research Questions & Answers

1) Do attitudes toward public transit affect public transit use? If so, how do attitudes affect people's transit use? ✔

2) Does the built environment affect public transit use? If so, how does the built environment influence people's transit use? ✔

3) Do the attitudinal factors, neighborhood types or a combination of both explain the resulting transit use better?

Attitudes are strongly associated with transit choice. If attitudes are not taken into consideration, the effects of built environment and infrastructure provision will be over-estimated.

Future Directions

- Collect panel data that examines the effects of land-use change while keeping the respondent specific characteristics constant.
  - Panel data collected with changes to built environment
  - Panel data where respondents move

- Develop survey questionnaire to reflect people's attitudes toward residential neighborhood environments.

- Extend to other travel modes.

- Comparative studies using similar data from different campuses.

INTEGRATED LAND-USE & TRANSPORTATION MODELS

Linking Land-Use & Travel in Ohio

- Develop a user-friendly modeling tool to develop forecasts based on different land use, transportation and policy scenarios.

- Enhance the existing Land Allocation model developed by MORPC (Mid-Ohio Regional Planning Commission)
  - Land allocation model gives forecasts of future land development under different scenarios.

- Add a transportation component to be able to forecast the implications of future land-use and infrastructure decisions on the resulting travel patterns.

- Study funded by Ohio Department of Transportation.
  Co-PI: Prof. Steven I. Gordon.

Why Look at Household Travel?

- Household travel accounts for the vast majority (over 80 %) of miles traveled on US roadways and three-quarters of the CO_2 emissions from mobile sources (FHWA, 2009).

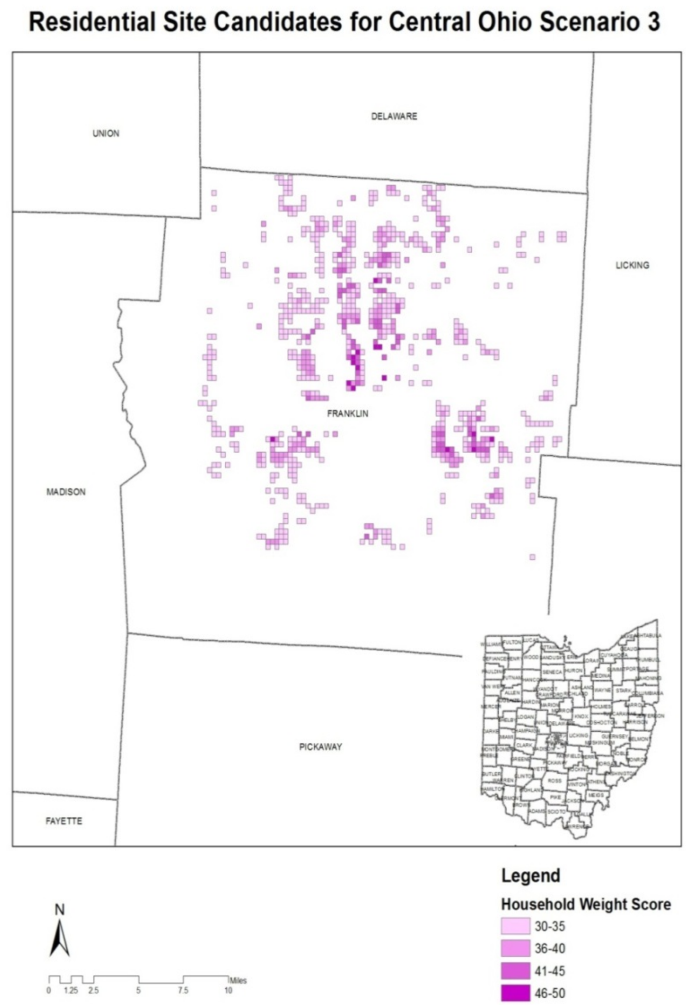
- The carbon footprint of daily travel=
  - f (types of vehicles, fuel efficiency, number of miles traveled).

- There is need to improve our understanding of the links between the land use, transportation policies and individual/household travel behavior to develop sound policies and investment decisions.

- The technological innovations alone will not be enough to reach targeted reductions in emissions, as the projected increase in vehicle miles traveled will outpace the advances in fuel economy and lower carbon fuels.

Land Allocation Component

- Allocate population and employment
  - Region divided into 40 acre cells
  - Cells characterized by current land-use and factors that would influence future development
  - Factors used to create score that dictates which cells would develop first
  - Development capped by regional growth control forecast



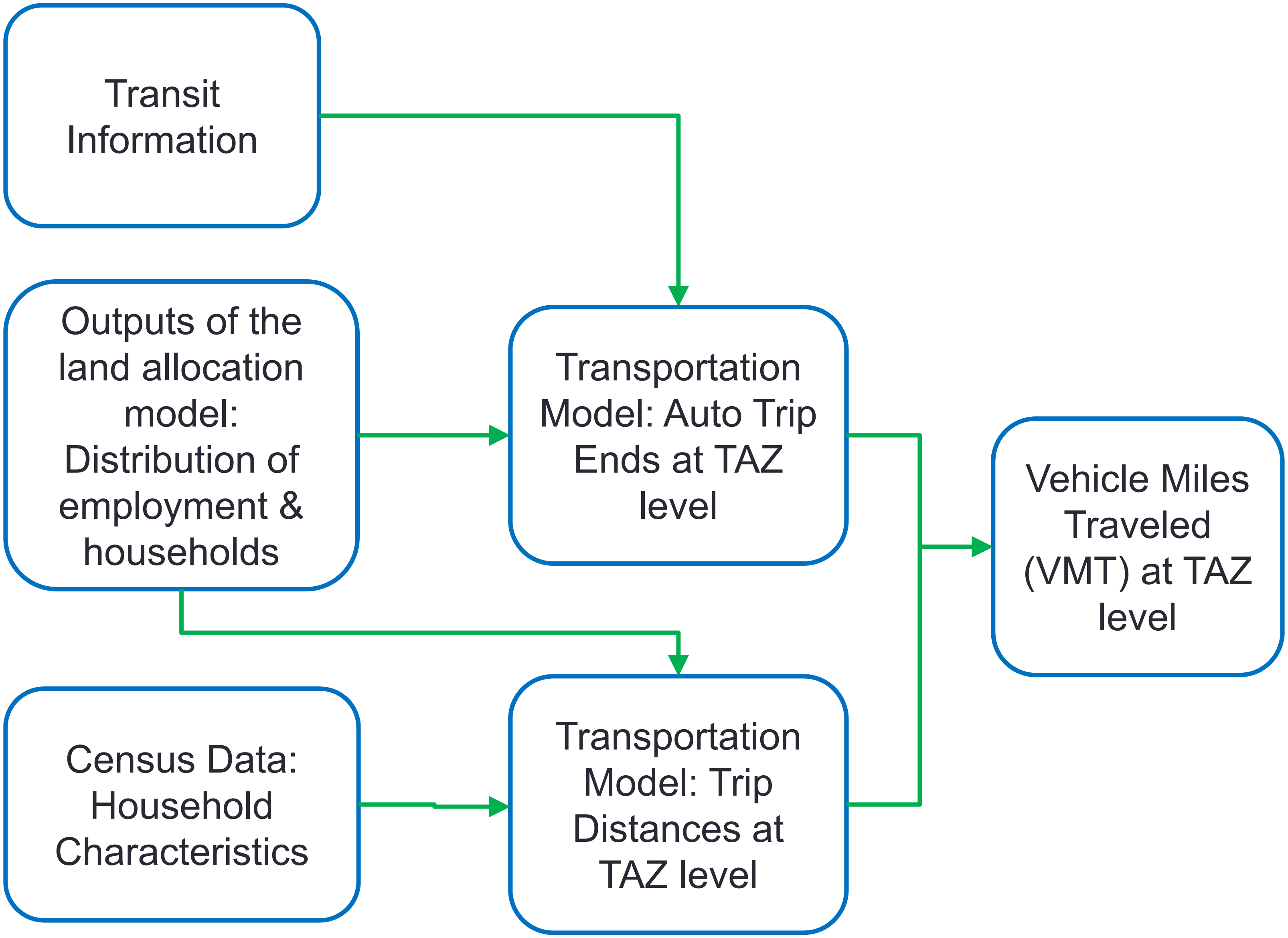
Major Score Categories

- Economic development factors
  - Cell in one of several economic development districts
- Infrastructure availability
  - Availability of sewer, water, recreation, transportation
- Environmental limitations
  - Constraints related to conservation areas, floodplains, slopes, etc.
- Nuisance limitations
  - Airport noise, quarries, landfills, wastewater treatment plants

Examples:

Category	Feature		Long description	Score
Econ Dev	TIF	TIF	Majority of grid in Tax Increment Financing (TIF) district	8
Econ Dev	CRA	CRA	Majority of grid in Community Reinvestment Area (CRA)	5
Environ	Forests	FOREST	More than 25% of grid with land cover of forest	-4
Environ	Streams (1/4 mile)	STREAM	Majority of grid within 1/4 mile of rivers and streams	-4
Environ	Wellhead Zone 5-year	WELL5	Majority of grid in Ohio EPA modeled 5-Year Wellhead Zone related to ground water wells	-4
Environ	High Slope (>24 %)	SLOPE	Majority of grid has slope greater than 24% in soil survey data	-4
Environ	Upstream from water in-take	CMZ	Majority of grid in Ohio EPA defined Corridor Management Zone (CMZ) related to surface water intakes	-6
Environ	Ground Reservoirs	UPRES	Majority of grid within 1/4 mile of ground reservoirs	-2

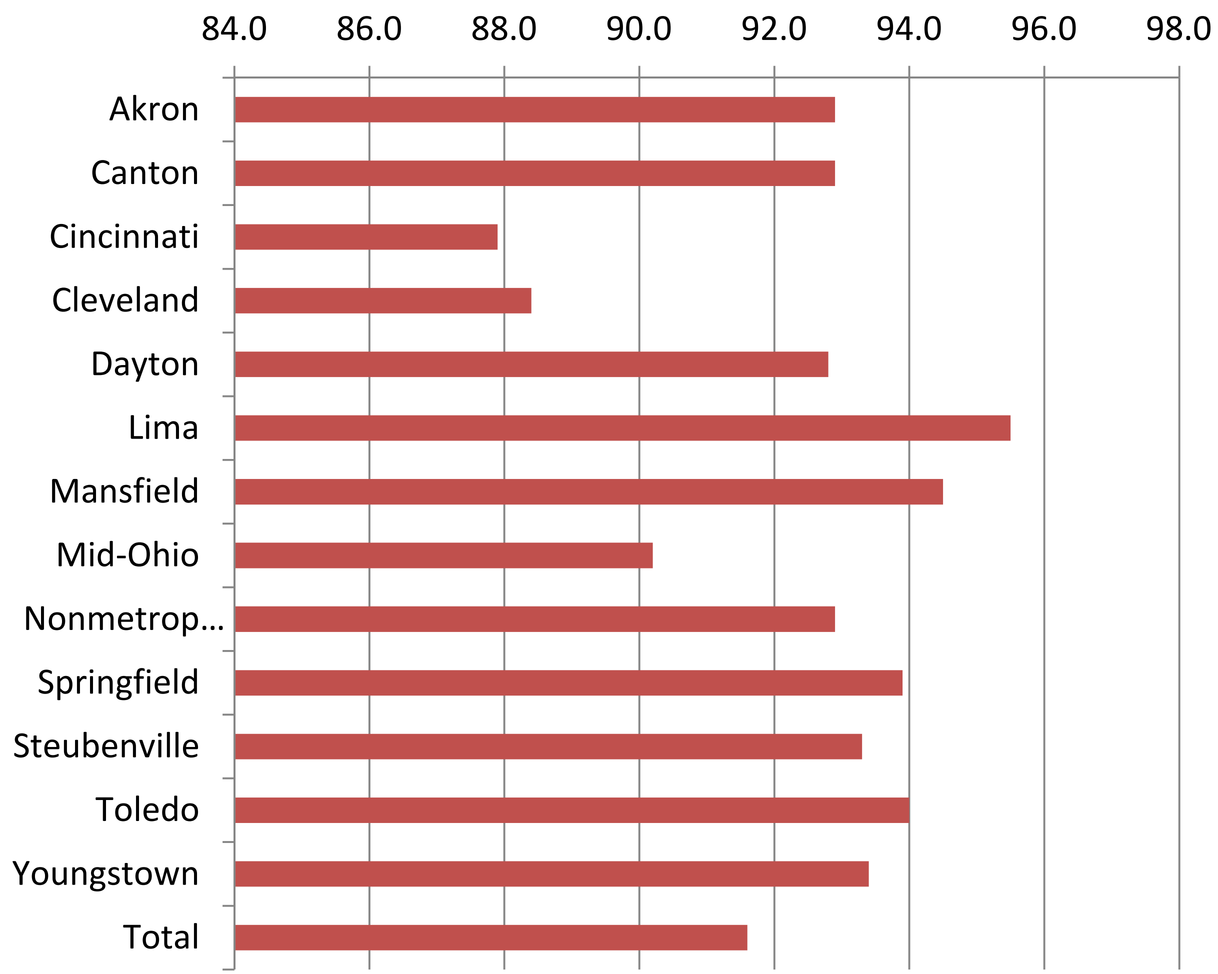
Transportation Component



Approach

- Given a land allocation scenario:
  - How many auto-trips will be generated?
  - What will be the mean trip length?
  - What will be the resulting VMT?
- Data:
  - Household travel surveys across OH.
    - Approximately 23,000 households
    - Over 200,000 trips
  - Census
  - Transit Agencies
- Two transportation models
  - Auto trip ends at TAZ level
  - Auto trip distances at TAZ level

Percentage of Auto Trips



Source: Household Travel Surveys

Auto Trip Ends

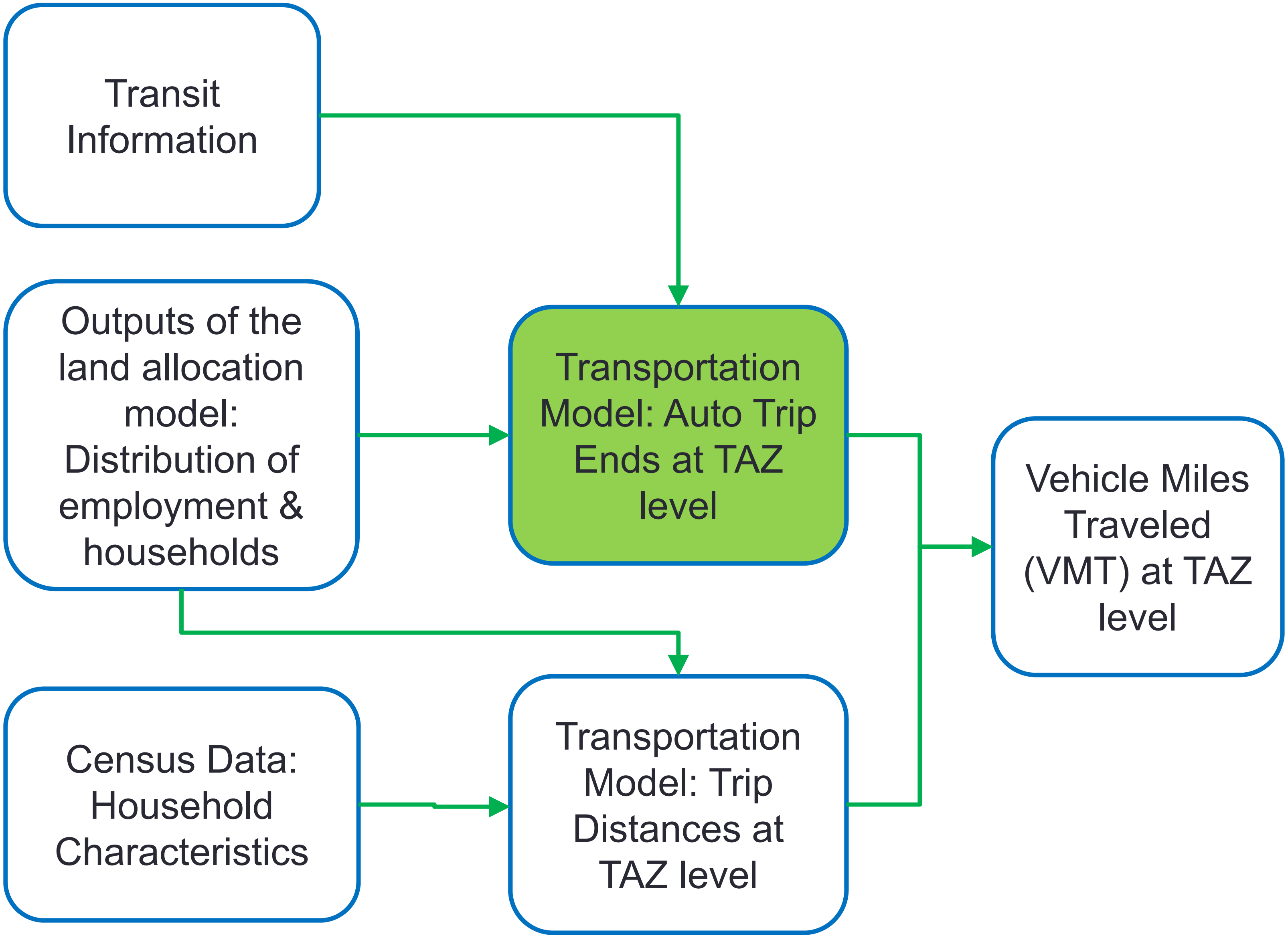
	Mean	Std. Dev.	N
Akron	16,261	11,706	215
Canton	14,339	13,417	133
Cincinnati	16,894	12,998	432
Cleveland	23,485	17,140	460
Dayton	14,154	13,336	296
Lima	10,888	10,236	50
Mid-Ohio	19,745	22,903	412
Mansfield	10,521	10,184	63
Non-metro	11,403	15,157	1,127
Springfield	10,555	9,194	66
Steubenville	5,708	7,225	66
Toledo	17,514	15,134	175
Youngstown	14,762	14,534	165
Total	15,427	16,123	3,660

Source: Outputs of the Ohio Statewide Model

Mean Trip Length (Auto Trips- miles)

	Mean	Std. Dev.	N
Akron	7.45	3.69	210
Canton	6.65	2.83	131
Cincinnati	7.30	3.33	426
Cleveland	7.19	3.58	429
Dayton	7.54	4.82	285
Lima	6.95	2.44	47
Mid-Ohio	8.38	5.44	359
Mansfield	7.40	5.53	63
Non-metro	9.23	5.82	897
Springfield	6.91	2.35	64
Steubenville	8.05	3.83	60
Toledo	6.36	3.32	172
Youngstown	6.21	2.74	164
Total	7.83	4.65	3,307

Source: Household Travel Surveys



Transit Information
Outputs of the land allocation model: Distribution of employment & households
Census Data: Household Characteristics
Transportation Model: Auto Trip Ends at TAZ level
Transportation Model: Trip Distances at TAZ level
Vehicle Miles Traveled (VMT) at TAZ level

Auto Trip Rates

- Estimate auto trip rates at TAZ level as a function of:
  - Number of households
  - Retail employment
  - Industrial employment
  - Office employment
  - Other employment
  - Availability of transit

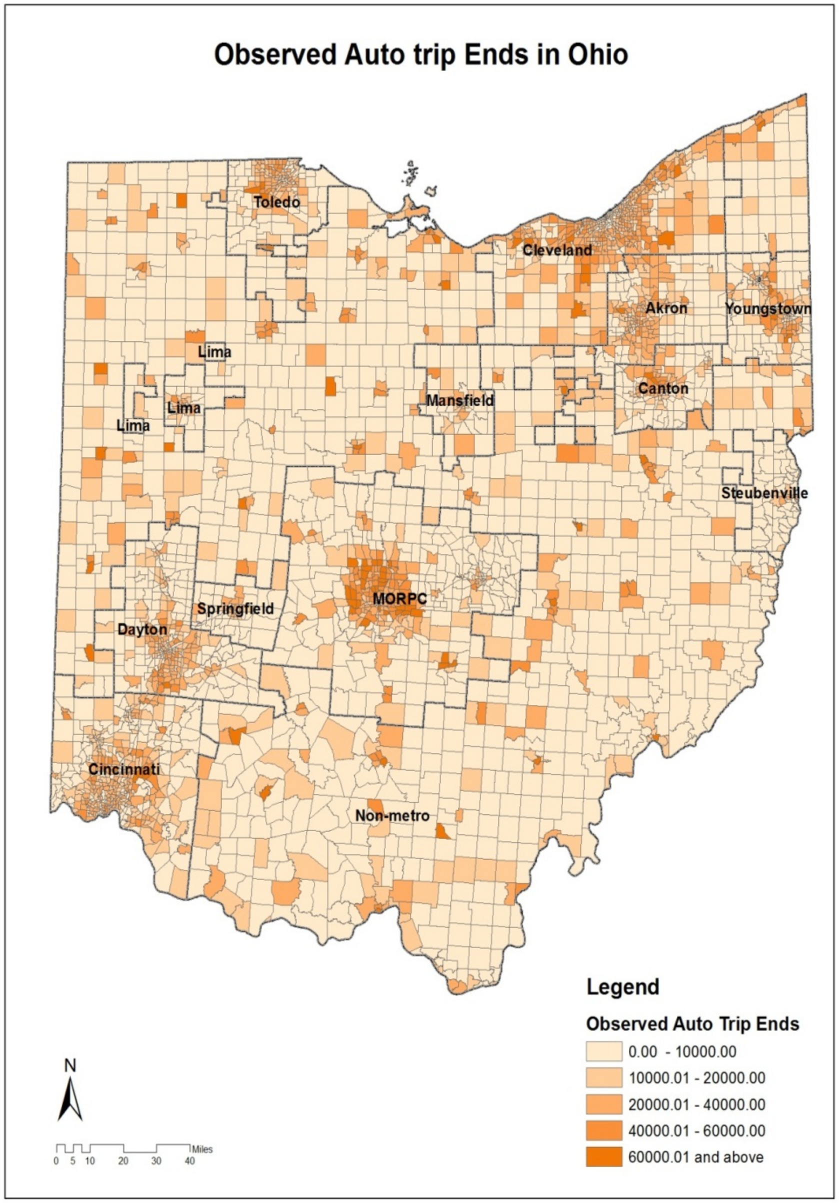
- Separate models for metro and non-metro areas
- Dependent variable: Number of auto trips generated at each TAZ.

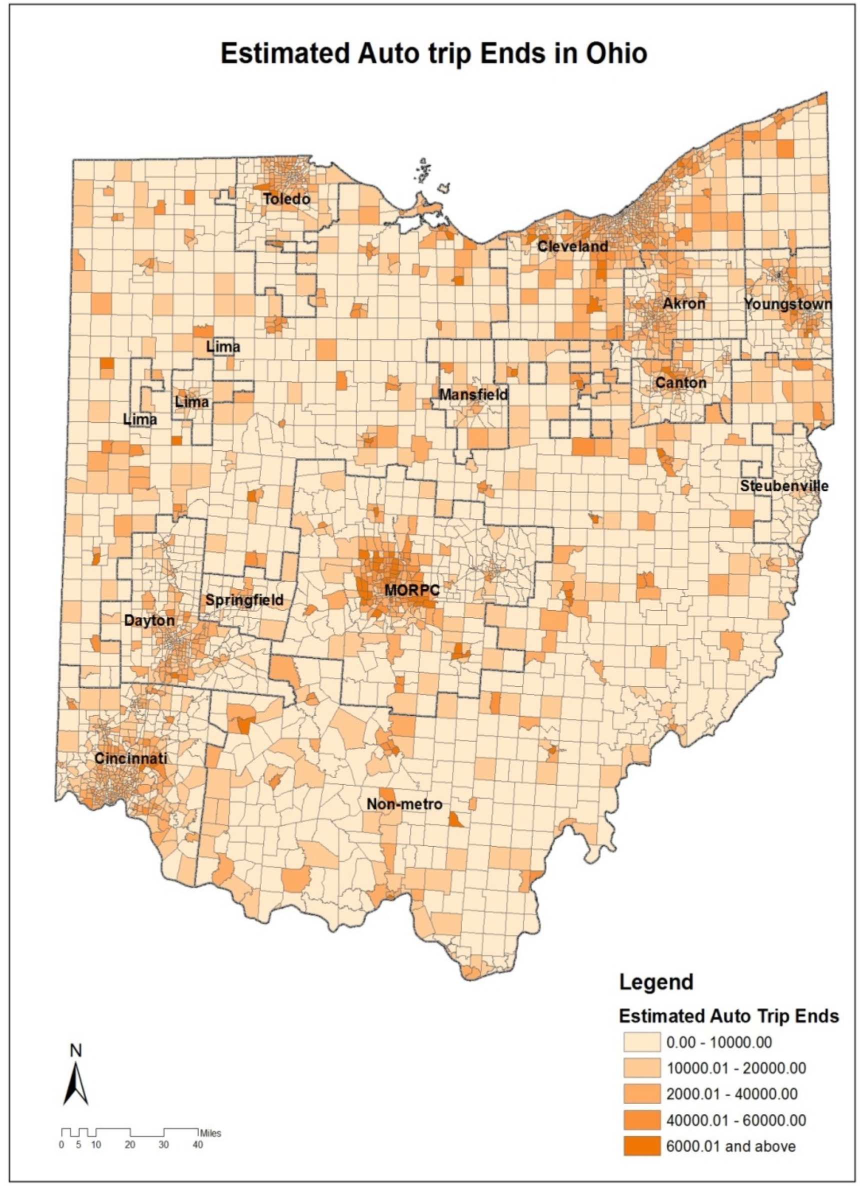
Auto Trip Ends – Metro Areas

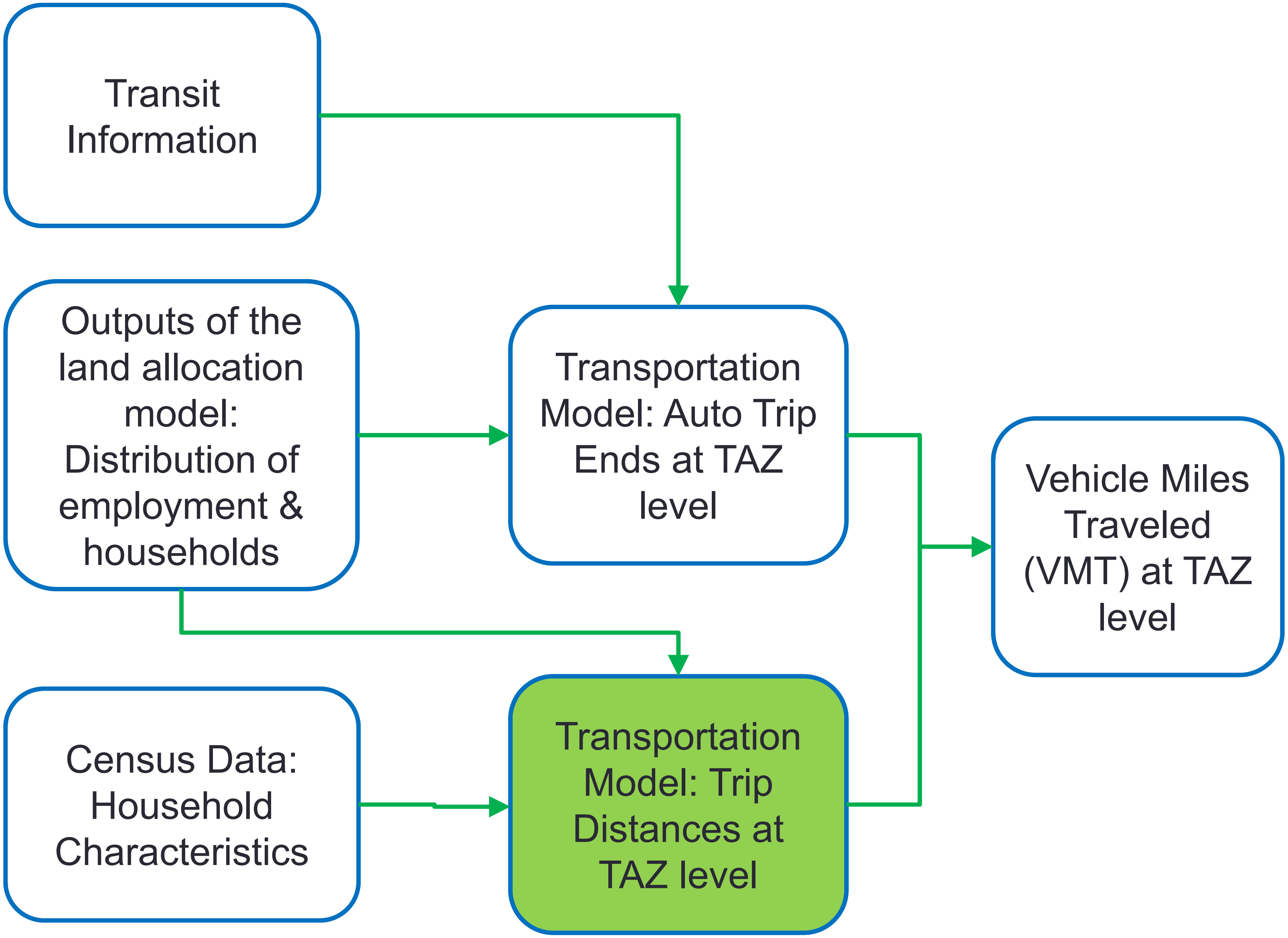
Dependent variable= Number of auto trip ends		
	Coefficient	t stat.
Households	**8.553**	**149.57**
Retail employment	**9.597**	**43.99**
Industry employment	**1.770**	**19.75**
Office employment	**1.606**	**7.39**
Other employment	**1.259**	**7.44**
Retail X transit availability	**-2.175**	**-8.69**
Office X transit availability	**-0.466**	**-2.05**
Other X transit availability	**-0.483**	**-2.74**
Number of observations		2533
R^2		0.9718
Adjusted R^2		0.9717

Auto Trip Ends – Nonmetropolitan Areas

Dependent variable= Number of auto trip ends		
	Coefficient	t stat.
Households	**7.744**	**75.5**
Retail employment	**10.985**	**47.48**
Industry employment	**2.264**	**17.59**
Office employment	**3.810**	**18.34**
Other employment	**2.319**	**14.36**
Number of observations		1,127
R^2		0.9851
Adjusted R^2		0.9850


Observed Auto trip Ends in Ohio
Toledo
Cleveland
Akron
Youngstown
Lima
Lima
Lima
Mansfield
Canton
Steubenville
MORPC
Springfield
Dayton
Cincinnati
Non-metro
Legend
Observed Auto Trip Ends
0.00 - 10000.00
10000.01 - 20000.00
20000.01 - 40000.00
40000.01 - 60000.00
60000.01 and above
N
Miles
0 5 10 20 30 40


Estimated Auto trip Ends in Ohio
Toledo
Cleveland
Akron
Youngstown
Lima
Lima
Lima
Mansfield
Canton
Steubenville
MORPC
Springfield
Dayton
Cincinnati
Non-metro
Legend
Estimated Auto Trip Ends
0.00 - 10000.00
10000.01 - 20000.00
2000.01 - 40000.00
40000.01 - 60000.00
6000.01 and above
N
Miles
0 5 10 20 30 40



Transit Information
Outputs of the land allocation model: Distribution of employment & households
Census Data: Household Characteristics
Transportation Model: Auto Trip Ends at TAZ level
Transportation Model: Trip Distances at TAZ level
Vehicle Miles Traveled (VMT) at TAZ level

Trip Distances

- Dependent variable: *ln (trip distance)*
- Variables of interest:
  - TAZ characteristics (employment & population).
  - Household characteristics at the TAZ level
  - Job – Household index within 15 minute travel time of the TAZ.
    - Measures balance between employment and households. Ranges from 0 to 1. It is equal to 0 if only households or employment present; to 1, when there is 1 job per household.
    - Job – Household index =

      1 - [ABS (employment - households) / (employment + households)]

Trip distance model: *ln (distance)*

	Coef.	t	Elasticities
Household size	0.0816	1.87	0.208
Household income (in $10k)	-0.0591	-6.22	-0.255
Vehicles per household driver	0.3815	8.04	0.721
Retail density	3.50E-05	-2.83	0.009
Industry/office/other density	6.86E-06	5.06	0.009
Household density	-0.0002	-12.06	-0.093
Job-Household index	-0.2427	-2.39	-0.187
Akron	-0.0546	-1.61	-5.310
Canton	-0.2313	-5.20	-20.646
Dayton	-0.0954	-2.97	-9.097
Lima	-0.1917	-2.74	-17.441
Mansfield	-0.2148	-3.52	-19.333
Non-metro	-0.1292	-4.69	-12.122
Springfield	-0.1591	-2.64	-14.713
Steubenville	-0.1219	-1.90	-11.474
Toledo	-0.1879	-4.84	-17.134
Youngstown	-0.2725	-6.62	-23.855
Constant	1.6489	13.33	

N= 2878,
Adjusted R^2= 0.19

Scenarios of Development

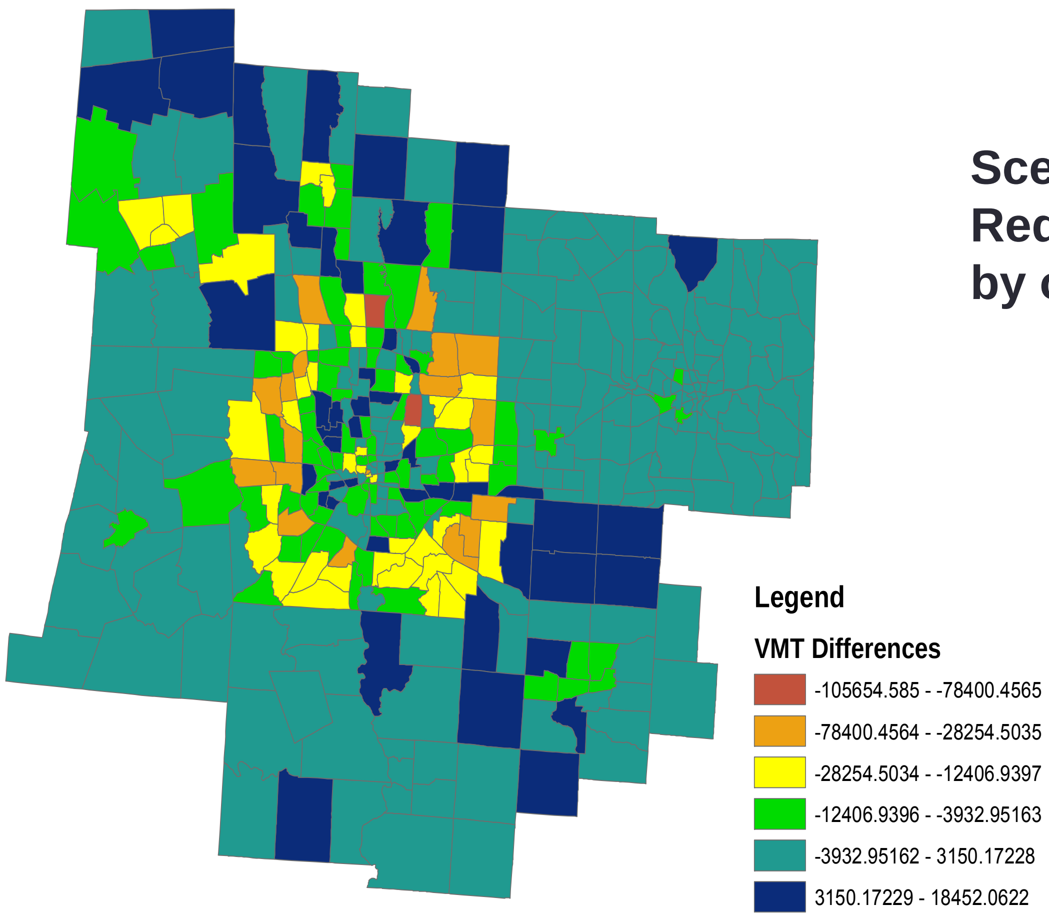
- Scenario 1
  - Continuation of current trends over forecast period (2000 – 2035)
  - Constrained by forecasts of 2035 household and employment forecasts
- Scenario 2
  - Site specific impacts of two potential major employment sites
  - Calculation of impacts on trips in directly impact TAZs and those adjacent
- Scenario 3
  - Higher density development of residential areas in Mid-Ohio to reflect possible changes in energy and housing costs
  - Modest reversal of decline trends in the central counties of other Ohio regions to reflect recovery of the economy over the long term
- Scenario 4
  - Scenario 3 impacts with increases in transit availability

Mid-Ohio Region
2000 vs. 2035 Comparison (Base Case)

	2000	2035	Change	% Change
Num of hh	707,979	901,808	193,829	27.38
Num of jobs	867,548	1,119,444	251,896	29.04
Office jobs	365,221	451,054	85,833	23.50
Retail jobs	197,758	257,390	59,632	30.15
Industry jobs	158,904	206,063	47,159	29.68
Other jobs	145,665	184,480	38,815	26.65
Number of trips	4,249,042	5,450,601	1,201,558	28.28
VMT	26,846,612	37,636,168	10,789,556	40.19
Trip distance	6.32	6.90	0.58	9.26

Results for Central Ohio:
Current trends vs. Scenario 3 (higher densities)

Central Ohio VMT Differences with Higher Density Residential



Scenario Results in Reduction in VMT by over 1.9 million

Current Project: Adding New Components

1. Decline:

- A better understanding of the impacts of declines in population & employment

2. Vehicle choice:

- The carbon footprint of daily travel=

  f (types of vehicles, fuel efficiency, number of miles traveled).

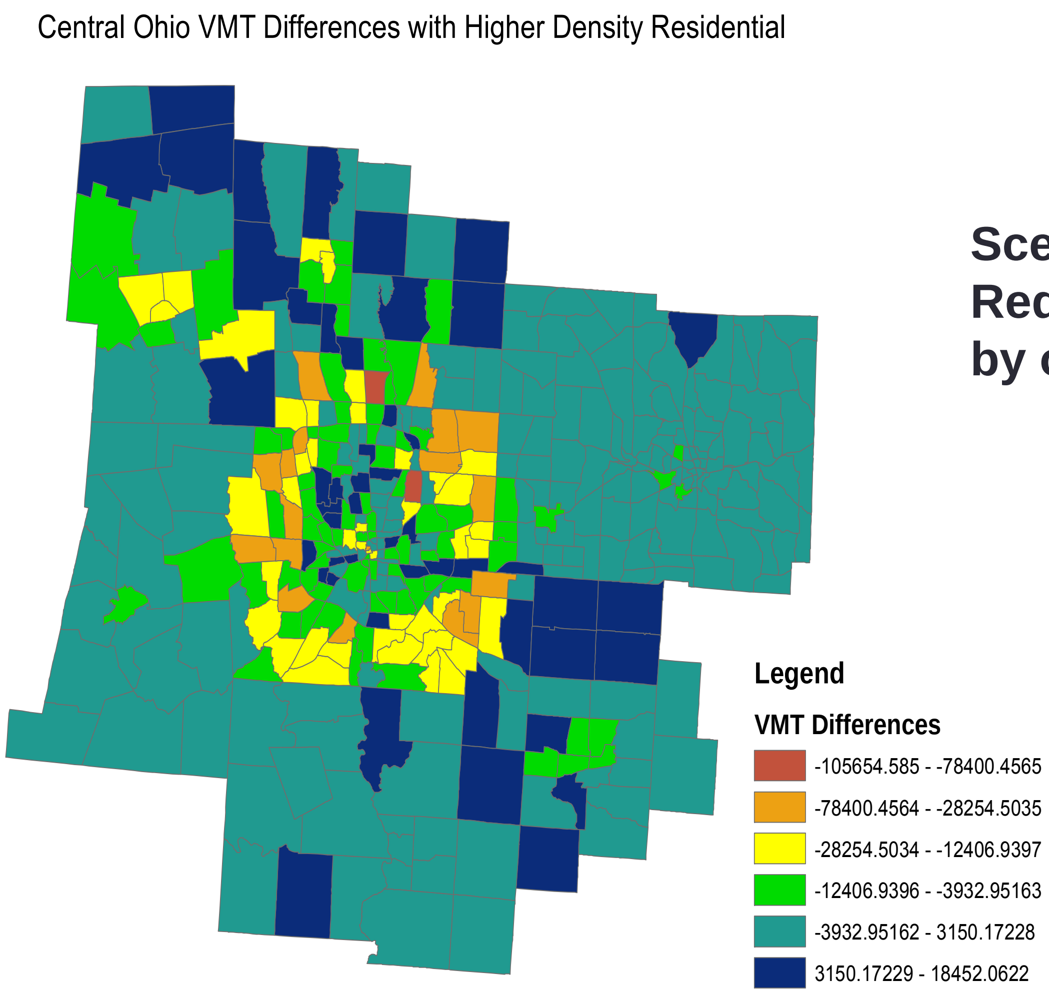
- 2009-2010 Cincinnati Metropolitan Area Household Travel Survey
- 2012-2013 Greater Cleveland Household Travel Survey

- Vehicle Types:
  - Passenger car
  - Passenger truck (SUV, pickup truck & van)

Variables of Interest

- Socio-demographics:
  - Primary drivers' characteristics
  - Household characteristics
  - TAZ level characteristics
- Transit access
- Built environment (TAZ level)
  - Job-Population Balance Index
  - Employment density
  - Population density
  - Percent single detached housing
  - Intersection density

Results for Central Ohio:
Current trends vs. Scenario 3 (higher densities)



Scenario Results in Reduction in VMT by over 1.9 million

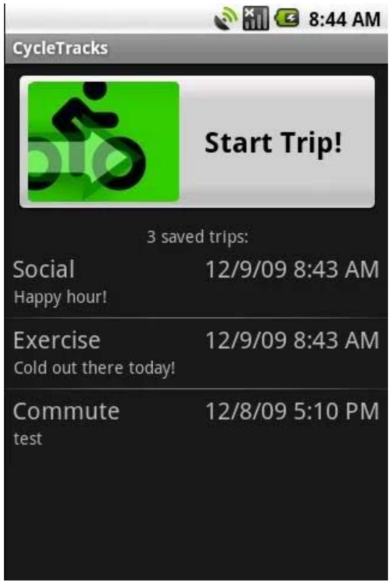
Concluding Remarks

- Two different projects at different scales
  - Individual
  - Local/regional
- The common thread: Forecasting future patterns under changing socio-economic, land-use and built environment scenarios.

- The ultimate goal is on supporting social and economic activities in complex urban systems by providing effective and responsive infrastructure and services that adapt and evolve with the ever-changing environments.

Ongoing Research

- Collecting data on bicycle trips (origins, destinations and route choices) through a cell phone app to model trip generation & distribution to aid in bicycle infrastructure decisions (proposal recently funded, NEXTRANS).



- Na Chen (PhD Candidate)
  - Activity space and built environment
- Yu-Jen Chen (PhD Candidate)
  - Joint versus individual tours & trip chains: Implications for VMT
- Michael Blau (MSc – just graduated)
  - Autonomous vehicles and infrastructure preferences for non-motorized modes

THANKS!

Questions?